Orig paper

Chapter 29

Irrigation of turfgrass below replacement of evapotranspiration as a means of water conservation : determining crop coefficient of turfgrasses (1)

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ABSTRACT

The objective of this research was to produce a broad set of data on turfgrass water requirements for warm and cool season species. Evapotranspiration was calculated from a standard U. S. Weather Bureau evaporation pan on turfgrass, together with other weather data including solar energy, wind, temperature, and humidity. Irrigation methodology was studied, soil water sensing was conducted with tensiometers, and neutron probe access tubes were used to calculate real-time water replacement. Water savings were evaluated to develop better irrigation practices in California and in other arid and semiarid regions. Three cool season grasses (Poa pratensis L., blend; Lolium perenne L., blend; and Festuca arundinacae Schreb., 'Kentucky-31') and three warm season grasses (Paspalum vaginatum L., 'Adalayd'-'Excalibre'; Cynodon dactylon (L.) Pers. x C. transvoalensis Burtt-Davy, Santa Ana hybrid bermudagrass; and Zoysia matrella (L.) Merv., 'Jade') were researched in a randomized block design with four replications.

The six grasses were irrigated at 100%, 80%, and 60% of calculated replacement evapotranspiration. Tensiometers were placed at 76 and 150 mm depths in the cool season grasses and 200 and 300 mm in the warm season grasses. Access tubes were installed in plots to a depth of 1200 mm in the cool season grasses and 1800 mm in the warm season. Scheduling was carried on by the water budget technique which was calculated on a weekly basis using wind modified pan evaporation data. State-of-the-art controllers were programmed with this irrigation scheduling information. The amount of irrigation was modified so that water did not pass below the 1200 and 1800 mm depths of the neutron probe access tubes during the irrigation season.

Crop coefficients, ET/EIpan, were determined for three years from applied water and evaporation pan data. They were found to be 0.7 for warm (w) season grasses, ETw/ETpan, and 0.8 for cool season grasses, EIc/EIp. This crop coefficient data was used to evaluate turfgrass responses of the six species to 60% and 80% of replacement evapotranspiration for water conservation.

Additional key words : Water conservation, Poa pratensis, Lolium perenne, Festuca arundinacea, Paspalum vaginatum, Cynodon dactylon, Zoysia matrella

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INTRODUCTION

The objective of this research was to produce a data set on turfgrass water requirements for warm and cool season grasses. Evapotranspiration and crop coefficients were determined using a standard U. S. Weather Bureau class A evaporation pan, together with a net radiometer, anemometer, and wet and dry bulb thermometers. Irrigation methodology was studied, soil water sensing was conducted with tensiometers, and neutron probe access tubes were used to calculate real-time water replacement. Water savings were evaluated to develop better irrigation practices in California and in other arid and semiarid regions. Three cool season grasses (*Poa pratensis* L., blend; *Lolium perenne* L., blend; and *Festuca arundinacae* Schreb., 'Kentucky-31') and three warm season grasses (*Paspalum vaginatum*, L., 'Adalayd'-Excalibre'; *Cynodon dactylon* (L.) Pers. x *C. transvoalensis* Burtt-Davy, Santa Ana hybrid bermudagrass; and *Zoysia matrella* (L.) Merv., 'Jade') were researched in a randomized block design with four replications.

The six grasses were irrigated at 100%, 80%, and 60% of calculated replacement evapotranspiration. Tensiometers were placed at 76 and 150 mm depths in the cool season grasses and 200 and 300 mm in the warm season grasses. Access tubes for neutron probe deep soil moisture determination were installed in plots to a depth of 1200 mm in the cool season grasses and 1800 mm in the warm season.

METHODS

Irrigation scheduling was conducted by the water budget technique. Irrigations were scheduled weekly using mm of evapotranspiration (ETgrass), for both warm season and cool season grasses. ETgrass is considered the evapotranspiration of applied water ETaw. The plots were divided into warm and cool season grasses and were sprinkler irrigated. ETgrass can be determined by using either the real-time method or the historical method. Both methods must assume a measured uniformity (CU). The C.U. was 87 percent and the extra water factor, $E.W.F._{90} = 1.35$: the statistical method of determining water applications to provide 1 unit volume of water to 90 percent of the surface area.

Real-Time Method

This method uses the reference ET (ETo) method described by Doorenbos and Pruitt, 1977, and a crop coefficient (Kc) estimated from previous turfgrass research by Marsh, et al., 1978. Reference ET (ETo) is calculated as:

$$ET_o = E_{pan} \times K_{pan} \qquad [1]$$

where the Kpan values are found in Table 18 of Doorenbos and Pruitt, 1977,.

The crop coefficients (Kc) for warm and cool season grasses were calculated assuming that maximum tensiometer readings of 40 cb and 35 cb are the most efficient limits for water use by warm and cool season grasses, respectively. Evaporation and water use data from the Marsh, et al., 1978, experiment were:

	Warm Season	Cool Season
Seasonal evaporation (BPI) pan	1194 mm	1301 mm
40 cb and 35 cb treatments	635 mm	1011 mm

A BPI evaporation pan evaporates approximately 80 percent of a class A pan, Doorenbos and Pruitt, 1977, so the following annual Kp = (ET grass/Epan) values for grass were calculated as:

$$\text{Cool season Kp} = \frac{1011}{1301} \times .8 = 0.622$$

$$\text{Warm season Kp} = \frac{635}{1194} \times .8 = 0.426$$

ETgrass is calculated as:

$$\text{ETgrass} = \text{Epan} \times \text{Kp} = \text{Epan} \times (\text{Kpan} \times \text{Kc}) \quad [2]$$

and therefore

$$\text{Kp} = \text{Kpan} \times \text{Kc} \quad [3]$$

and

$$\text{Kc} = \frac{\text{Kp}}{\text{Kpan}} \quad [4]$$

The normal Kpan = (ETo/Epan) values in a maritime climate with 10 meters fetch is Kpan = 0.75, so the Kc = (ETgrass/ETo) for SCFS was calculated as:

$$\text{Cool season Kc} = \frac{0.622}{0.75} = 0.83 \qquad \text{Warm season Kc} = \frac{0.426}{0.75} = 0.57$$

Calculation of ETgrass from pan evaporation involves two steps:

Step 1: The pan data are multipled by the constant crop coefficient (Kc).

Step 2: The product is multiplied by the pan coefficient (Kpan), which adjusts for variations in wind and humidity.

Historical Method

The historical method of determining ETgrass was calculated using Kp values determined from previous research by Marsh, et al., 1978, Eq. 5.

$$\text{ETgrass} = \text{Epan} \times \text{Kp} \quad [5]$$

The Kp values vary from month to month in order to account for normal variations in the climate at the South Coast Field Station (SCFS) and the growth curves of turfgrass. Table 1 lists the crop coefficients (Kp) for SCFS as well as California Department of Water Resources, 1975, estimates of reference ET (ETo) and the monthly Kc values (times .8) that can be used with the real-time method equation [2]. Conversion from mm of evapotranspiration to minutes of operation, irrigation time, is desirable and can be calculated as follows:

Calculate minutes of operation (MOO) multiplier using an $E.W.F._{90} = 1.35$.

$$\text{MOO} = \frac{\text{ETgrass} \times \text{EWF} \times \text{Area } (m^3 \times L/m^3}{\text{average application rate (L.P.M.)}} \quad [6]$$

The historical method was chosen for this project, daily Epan data were collected adjacent to the turf plots.

Eight and 60 percent ET were determined by multiplying 100 percent ET by .8 and .6, respectively.

RESULTS

The replacement water for the three irrigation requirements, ETgrass 100 percent, 80 percent, 60 percent, was calculated weekly by the historical method,[5], Table 1, and equation [6] for adjusting a solid state controller with a uniformity measure.

The Epan is measured daily: the uniformity of the sprinkler system was determined by can tests, yearly, to be 1.35 mm ($E.W.F._{90} = 1.35$). The formula used [6] and other factors are explained in the methods section.

Replacement of soil moisture can be scheduled daily or two or three times per week depending on the time of year and soil moisture depletion during a given period. The calculated water application treatments were imposed August 1, 1981, and were applied through December 31, 1983.

In 1982, the calculated water application and actual, Table 2, were about 1090 mm for 100 percent ETgrass cool season turfgrass. Warm season grasses were 864 mm. Rainfall which occurred primarily from November to March was 468.6 mm. The soil profile conservatively holds 300 mm depth of water in the top 1800 mm of soil. Rainfall did not appreciably affect the applied water (ETaw) during the primary growing season, April through November. Likewise, the 864 mm applied to the warm season grasses was not appreciably affected by nor was there evidence of deep percolation during the primary growing season. Only 101 mm of rain were measured during the growing season. The rainfall is subtracted from the original Epan reading and is, therefore, reasonably accounted for in the calculated applications. A comparison of calculated water application and actual in 1982 is shown in Table 2.

In 1983 a higher than normal rainfall season occurred with 807 mm of precipitation. However, the profile was filled during the winter and only 226 mm fell from April to October 30, 1983; of that, 121 mm occurred in early April. Water movement was found, below the root zone, only on June 29, August 29, October 5, and October 17 in all plots of 100 and 80 percent ET in 1983. Even during a higher than normal rainfall season, the actual applied water 983 mm cool season (1983) is similar to a drier year, 1982, with 1097 mm applied. Most of the 114 mm of implied higher usage by cool season grasses may have moved through deep percolation.

The warm season grasses actual application of 838 mm in 1982 and 864 mm in 1983 is not a large difference and indicates that careful scheduling can be conducted and water conserved in wet or dry seasons. Perhaps slight downward movement $\pm$ 25 mm occurred in the warm season grasses (Table 3).

DISCUSSION

Water conservation effectively saves about 20-40 percent of water needs when 60-80 percent of ETgrass is applied. The desirability of using warm season grasses in many areas of southern California with 60 to 80 percent of ETgrass versus cool season turfgrass at near 100 percent ETgrass indicates nearly a 50 percent savings of water, as shown in Table 5.

Crop coefficients, ET/ETpan, were calculated for nearly three years from applied water and evaporation pan data. They were found to be about 0.7 for warm (w) season grasses, ETw/ETpan, and 0.8 for cool (c) season grasses, ETc/ETpan.

The ETgrass/ETpan ratio cool season (.6) and warm season (.5) on a yearly basis is indicative of applications under near perfect efficiency. Application efficiency, Ea, is a major concern in conservation.

Table 1. Crop coefficients (Kp) from Marsh, et al.[3] (for historical method), reference ETo and Epan estimates from DWR data[1], crop coefficients Kc for real-time method.

Month	Kp Warm	Kp Cool	DWR Estimate[1] ETo mm	DWR Estimate[1] Epan mm	Kc Warm	Kc Cool
J	.44	.49	46	64	.55	.61
F	.43	.51	61	84	.54	.64
M	.61	.60	79	104	.76	.75
A	.58	.83	97	125	.72	1.04
M	.63	.76	114	147	.79	.95
J	.54	.70	130	168	.68	.88
J	.57	.75	140	178	.71	.94
A	.57	.69	140	178	.71	.86
S	.50	.59	114	147	.62	.74
O	.43	.60	86	117	.54	.75
N	.46	.55	66	91	.58	.69
D	.44	.48	56	79	.55	.60

Table 2. Comparison of calculated water application rate to actual water applied for 1982 (1/1/82 - 12/31/82)*.

Sprinkler Plots	Water Applied (mm)* Calculated[1]	Actual[2]	Application Ratio	Percent	Rainfall (mm)
Cool season					
100% ET	1090	1097	1.01	101	468.6
80% ET	871	889	0.82	82	
60% ET	653	676	0.62	62	
Warm season					
100% ET	848	864	1.02	102	
80% ET	678	696	0.82	82	
60% ET	508	549	0.65	65	

Table 3. Comparison of calculated water application rate to actual water applied for 1983 (1/1/83 - 12/31/83)*.

Sprinkler Plots	Water Applied (mm)* Calculated[1]	Actual[2]	Application Ratio	Percent	Rainfall (mm)
Cool season					
100% ET	1059	983	0.93	93	807
80% ET	848	810	0.76	75	
60% ET	635	622	0.59	59	
Warm season					
100% ET	853	838	0.98	98	
80% ET	683	655	0.77	77	
60% ET	513	498	0.58	58	

* Class A pan evaporation 1397 mm for 1982 and 1413mm for 1983.
1 Calculated from evaporation (Class A pan) minus rainfall.
2 Actual applied water from meters.

Table 4. Comparison of calculated water application rates to actual water applied (8/1/81 - 12/31/83)*.

Sprinkler Plots	Water Applied (mm)* Calculated[1]	Actual[2]	Application Ratio	Percent	Rainfall (mm)
Cool season					
100% ET	2609	2652	1.02	102	1357
80% ET	2088	2093	0.80	80	
60% ET	1565	1593	0.61	61	
Warm season					
100% ET	2080	2245	1.08	108	
80% ET	1644	1763	0.85	85	
60% ET	1247	1339	0.64	64	

* Class A pan evaporation 3397 mm for 8/1/81 to 12/21/83.
1 Calculated from Class A pan--rainfall occurrence.
2 Actual applied water from meters.

Table 5. A summary of the cool and warm season turfgrass appearance ratings and the water applied for the duration of the study. Performance rating 1-9, with 9 best.

Irrigation Regime	Turf Appearance 8/81 - 12/83			Water Applied (mm) Actual	ETgrass[1]
Cool season:	*P. pratensis*	*L. perenne*	*F. arundinacea*		
100% ET	5.5 y*	6.2 y	5.8 y	2652	1963
80% ET	5.3 y	5.9 y	5.7 yz	2093	1549
60% ET	4.8 z	5.0 z	5.3 z	1593	1179
Warm season:	*Cynodon* sp.	*P. vaginatum*	*Z. matrella*		
100% ET	6.5 ns**	5.8 ns	5.6 x	2245	1664
80% ET	6.5	5.8	4.8 y	1763	1306
60% ET	6.4	5.4	4.2 z	1339	991

1 ETgrass equals the actual applied water divided by the Extra Water Factor (EWF_{90}) which is 1.35.
* Values followed by common letters are not significantly

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SUMMARY IN FRENCH

L'irrigation des graminées à gazon à des doses inférieures à l'évapotranspiration comme moyen de conservation de l'eau : détermination du coefficient d'utilisation de l'eau chez les graminées à gazon.

L'objectif de cette étude était de fournir le maximum de résultats sur les besoins en eau des espèces à gazon de "saison froide" et de "saison chaude". L'évapotranspiration a été calculée à partir d'un évapotranspiromètre standard de l'U.S.Weather Bureau ainsi que d'autres données météorologiques telles que l'énergie solaire, le vent, la température, l'hygrométrie. De plus la méthodologie de l'irrigation fut étudiée, la perception de l'eau du sol fut effectuée à l'aide de tensiomètres et des sondes à neutrons furent utilisées pour calculer le temps réel de remplacement de l'eau. Des économies d'eau furent évaluées afin de développer de meilleures pratiques de l'irrigation en Californie et dans d'autres régions arides et semi-arides. Trois espèces de "saison froide" (un mélange de cultivars de Poa pratensis L., un mélange de cultivars de Lolium perenne L. et la variété Kentucky 31 de Festuca arundinacea Schreb.) et trois espèces de "saison chaude" (les cultivars 'Adalayd' et 'Excalibre' de Paspalum vaginatum L., l'hybride Santa Anna de Cynodon dactylon (L.) Pers. croisé avec C.transvaalensis Burtt-Davy et la variété 'Jade' de Zoysia matrella (L.) Merv. installées dans un essai en blocs randomisés furent utilisées pour ce travail.
Les six graminées reçurent des apports d'eau de 100 % , 80 % et 60 % de l'évapotranspiration calculée. Des tensiomètres furent placés dans le sol à des profondeurs de 76 et 150 mm dans les parcelles des espèces de "saison froide" et à des profondeurs de 200 et 300 mm dans celles des espèces de "saison chaude". Les tubes pour sondes à neutrons furent descendus à des profondeurs respectivement de 1200 et 1800 mm dans les parcelles des espèces de "saison froide" et celles de "saison chaude". Le programme d'irrigation a été réalisé selon la technique du bilan hydrique qui était calculé chaque semaine en utilisant les données de l'évapotranspiromètre modifiées par le vent. Des contrôleurs furent programmés à partir de ce programme d'information de l'irrigation. La quantité d'eau apportée fut ajustée de façon que le niveau de l'eau ne descende pas en dessous de 1200 et 1800 mm, profondeurs des sondes à neutrons au cours de la saison d'irrigation.
Les coefficients d'utilisation de l'eau rapport : (ETP calculé)/(ET mesuré par évapotranspiromètre) déterminés sur 3 ans à partir des quantités d'eau apportées et des données de l'évapotranspiromètre. Ils furent trouvés égaux à 0,7 pour les espèces de "saison chaude" (w) et 0,8 pour les espèces de "saison froide" (c). Ces coefficients d'utilisation de l'eau furent utilisés pour évaluer les réponses des six espèces à gazon à des apports de 60 % et 80 % de l'évapotranspiration afin d'assurer une conservation de l'eau.